EXTRA DIMENSIONS AT LHC

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1. Introduction

Albeit in impressive agreement with experimental data, the Standard Model is unsatisfactory in the fact that it does not include the quantum effects of gravity.

A unified framework describing all fundamental interactions including gravity has been the holly grail of generations of theoretical physicists. One property that seems always required is the presence of additional degrees of freedom which in some limit are described as extra dimensions, where the "extra" stands for the fact that they add up to the known four-dimensional space-time ones. This is in particular the case in String Theory which is the best, if not the only today, consistent framework to incorporate all fundamental interactions. There, particles are identified with the lowest energy excitations of extended objects "strings". Present experimental energies are too low to excite the string oscillation modes therefore, these appear "point-like". These strings have new degrees of freedom that often can be viewed as propagating in extra dimensions and thus provide a compelling reason for the latter.

Study of extra dimensions as a framework of unification of fundamental interactions, is an old subject which goes back to Kaluza and Klein in the beginning of the twentieth century. Attempts to construct realistic models of the world with more than four dimensions have met a major obstacle for a long time. Fermions appear vector like while our world is made of chiral fermions. This obstacle is not present in some string theory models. In perturbative string theory, the scale of supersymmetry breaking is not a free parameter but it has to be of the same size as the scale of some compactified dimensions. In [1], it was suggested therefore that a dimension as large as the TeV^{-1} can be used to break supersymmetry and fix the gauge hierarchy problem. Given the absence of experimental constraint [?], in [3] for the first time the serious possibility that such extra-dimensions can be searched for at the LHC was proposed. Later, it was realised that if only gravity propagates in the extra-dimensions then these can be as large as in the sub-millimeter [4] and [5] while all matter and gauge interactions are localised on hyper-surfaces. This striking proposal opened a whole field of research on possible experimental observation of extra dimensions, with different properties due to choices of their geometry as warped or infinite size extra dimensions proposals [6,?]. Some of these are covered by the authors in this special issue. Elena Accomando reviews bounds on Kaluza-Klein (KK) excitations of Standard Model gauge bosons both set by the ElectroWeak Precision Test (EWPT) and the direct searches performed at the CERN Large Hadron Collider (LHC). The models have part of the matter localised at the boundaries and gauge bosons propagating into the bulk and acquiring KK excitations.

The case where all fields live in the bulk is discussed by Géraldine Servant. Such models attracted some attention because they have collider signatures very similar to supersymmetry. The main remark is that the region of interest in the parameter space will be investigated by the next LHC run.

In addition to the KK states themselves, there is a possibility to detect excitations of the strings as extended objects. This is discussed by Dieter Lust and Tom Taylor.

The experimental bounds on these scenarios derived at the LHC have been presented for ATLAS and CMS experiments.

Three important implications of extra dimensions for beyond the Standard model model building are discussed in this issue for specific compactifications. Mariano Quiros discusses how the recently discovered Higgs boson fits in a framework of extra dimensions, Gero Gersdorff discusses the implication on flavour physics. Tony Gherghetta illustrates how warped extra dimensions can play a role in understanding the mechanism of supersymmetry breaking.

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